Netjack - Remote music collaboration with electronic sequencers

by Alexander Carôt and Torben Hohn

1.) Introduction

2.) Theory of remote musical interaction

3.) Alternative approaches

4.) Remote music collaboration with electronic sequencers
(Netjack)

1.) Introduction

The current state :

Old Studer Tape Machine

-In the old days: analogue signal processing

-PC has revolutionized the domain of audio engin

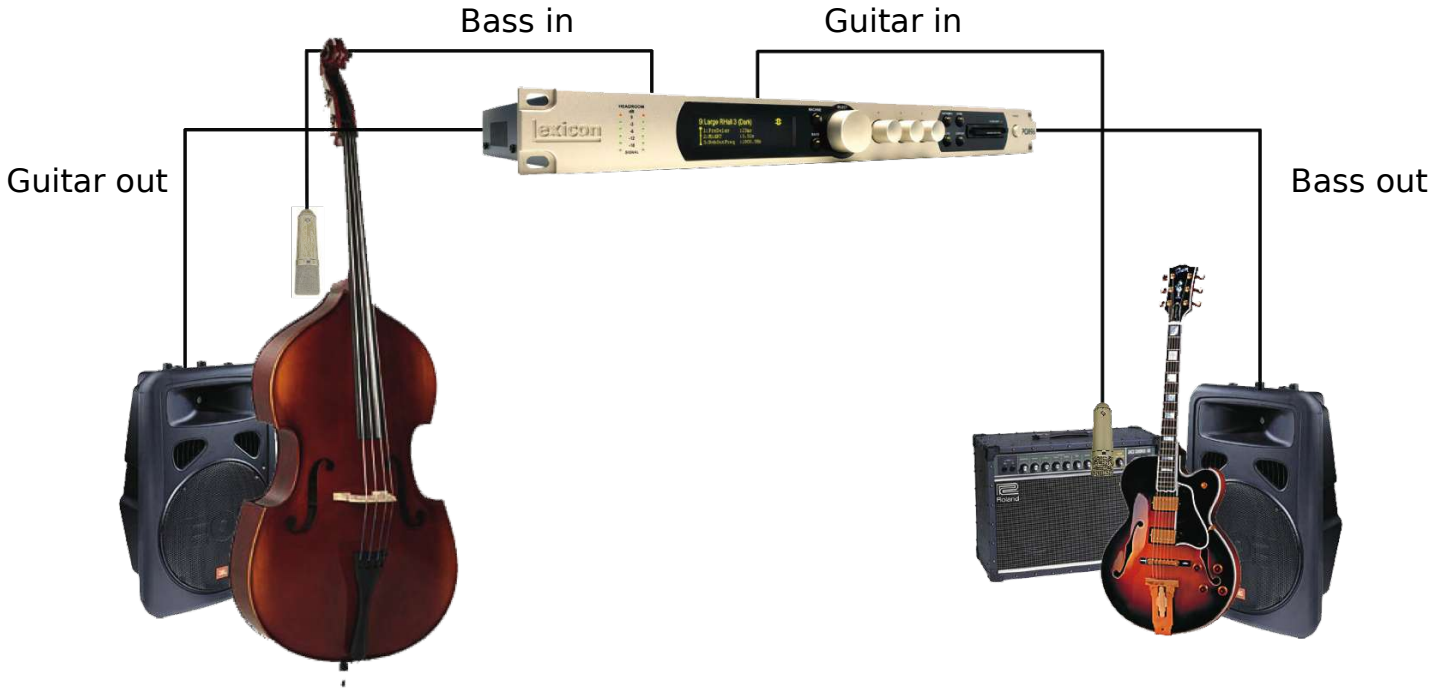
-HD recording / editing / mastering

-prof. software e.g.: Ardour, Cubase, ProTools etc

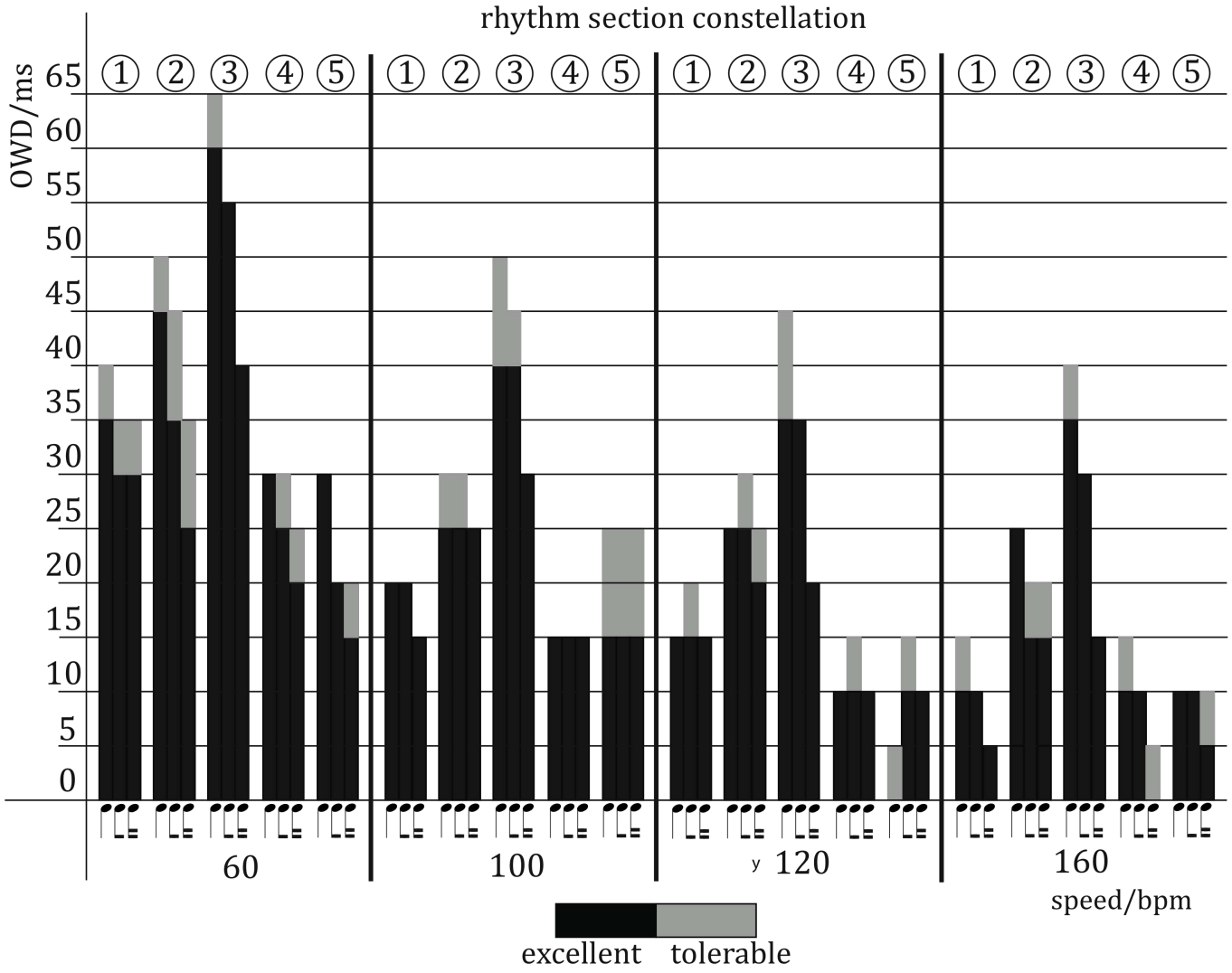
-MP3, Ogg Vorbis Files → sharing / exchange

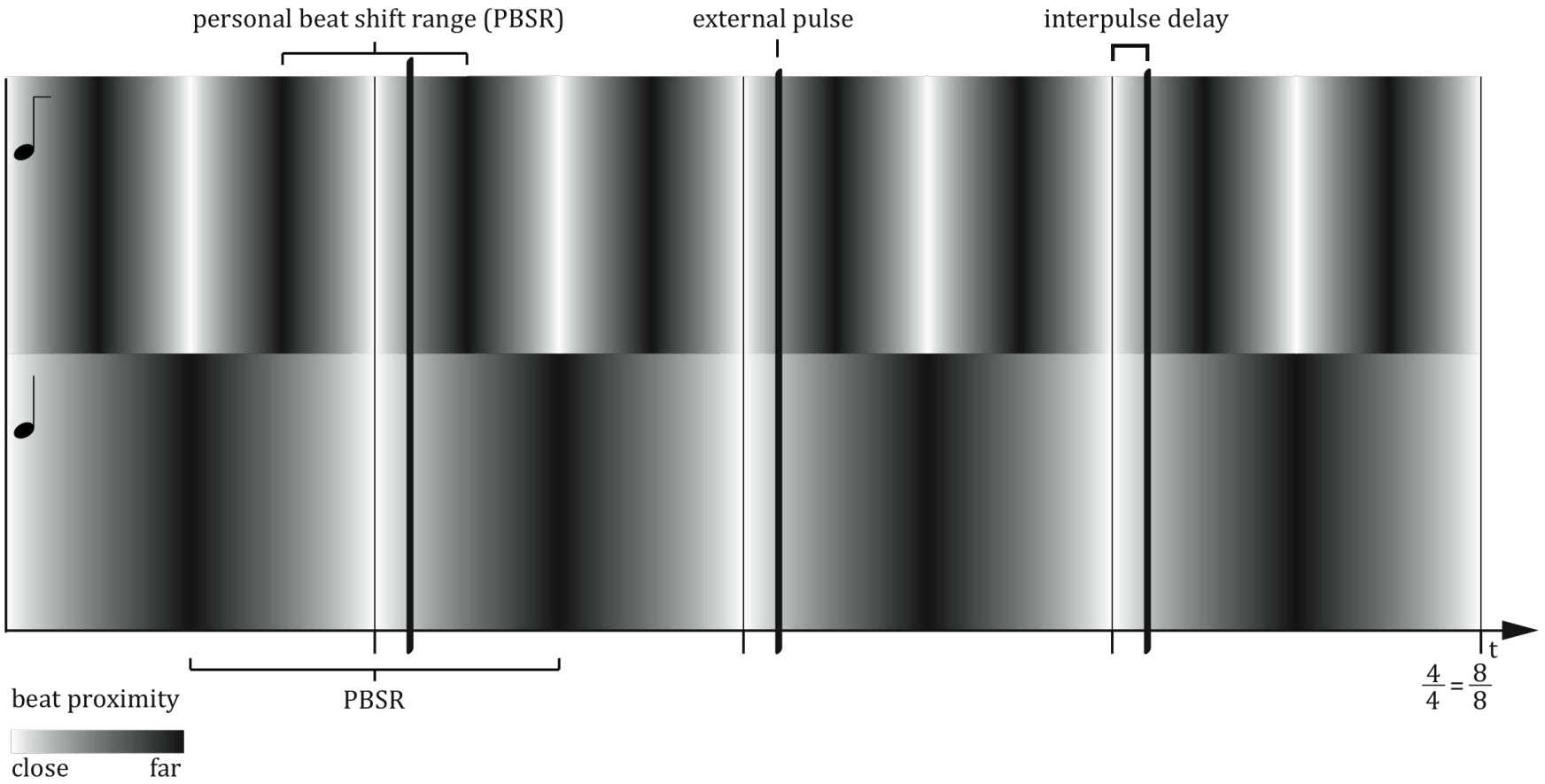
Real musical interplay ?

2) Theory of remote musical interaction



- Cognitive Science: Integration Processes
- Ira J. Hirsh : Threshold for order identification = 20 ms
- Slightly higher for interactive music : Schuett/Chafe EPT = 30 ms


rhythm section constellation
OWD/ms
65
60
55
50
45
40
35
30
25
20
15
10
5
0
① ② ③ ④ ⑤
60
100
120
160
speed/bpm
excellent
tolerable



EDAL (Ensemble Delay Acceptance Threshold)

45 ms Delay

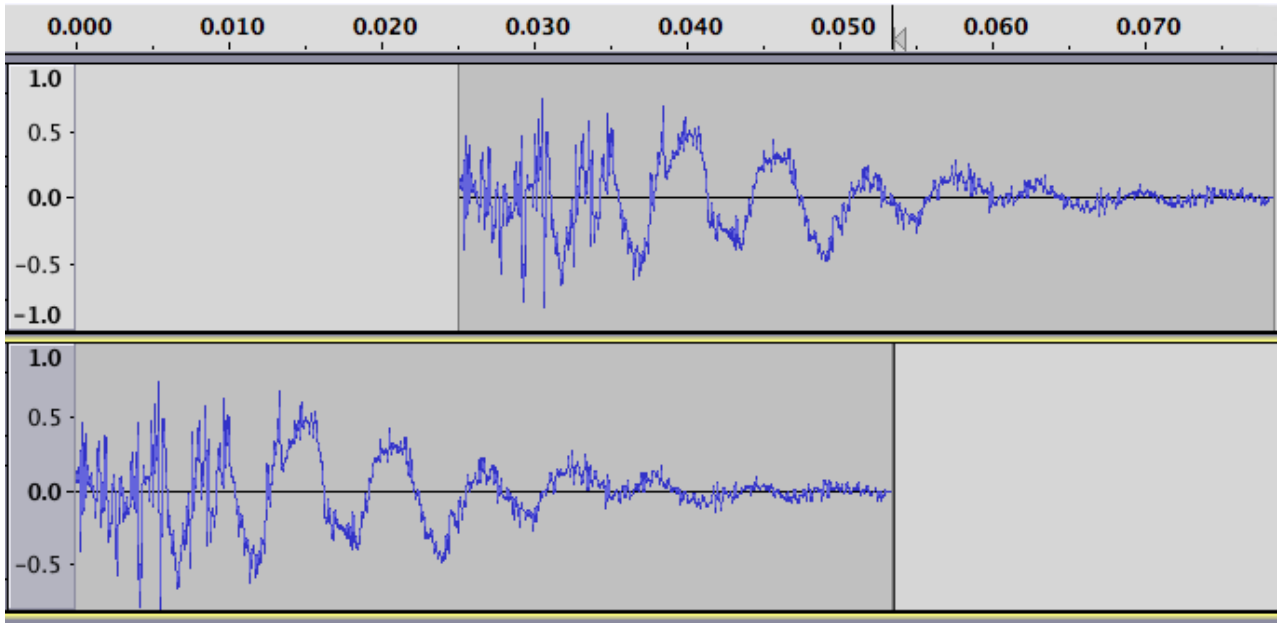
35 ms Delay

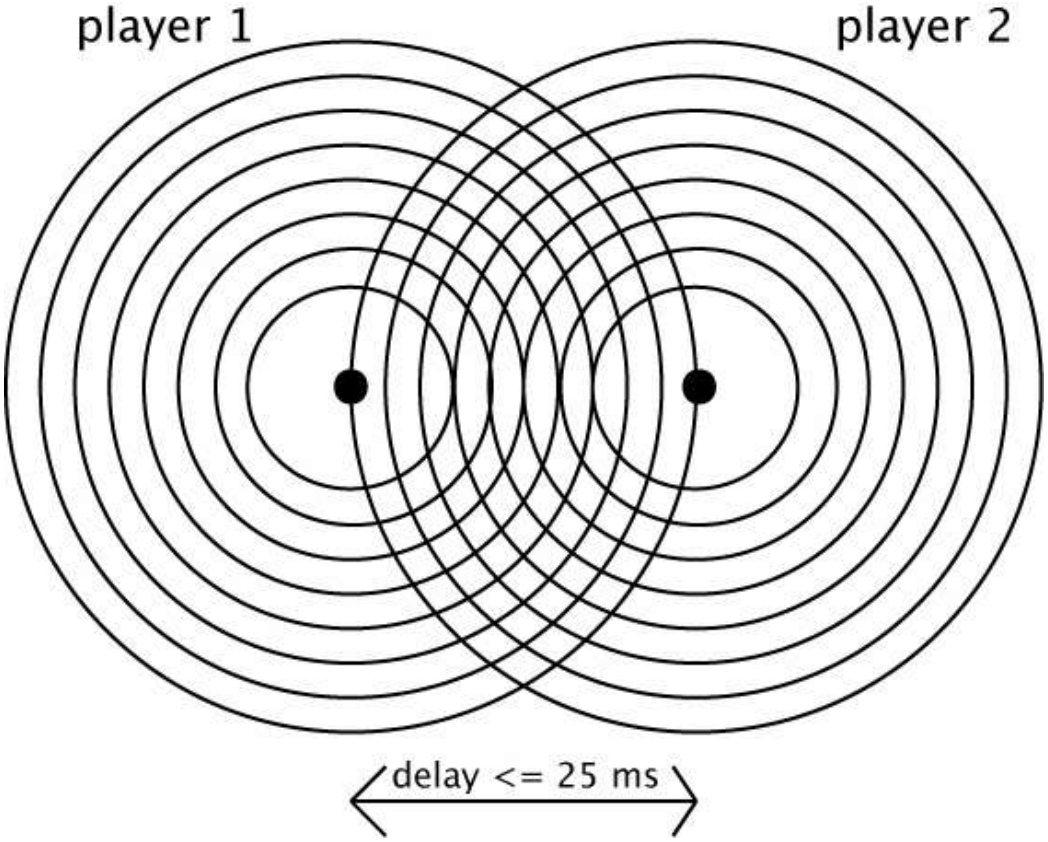
25 ms Delay

20 ms Delay

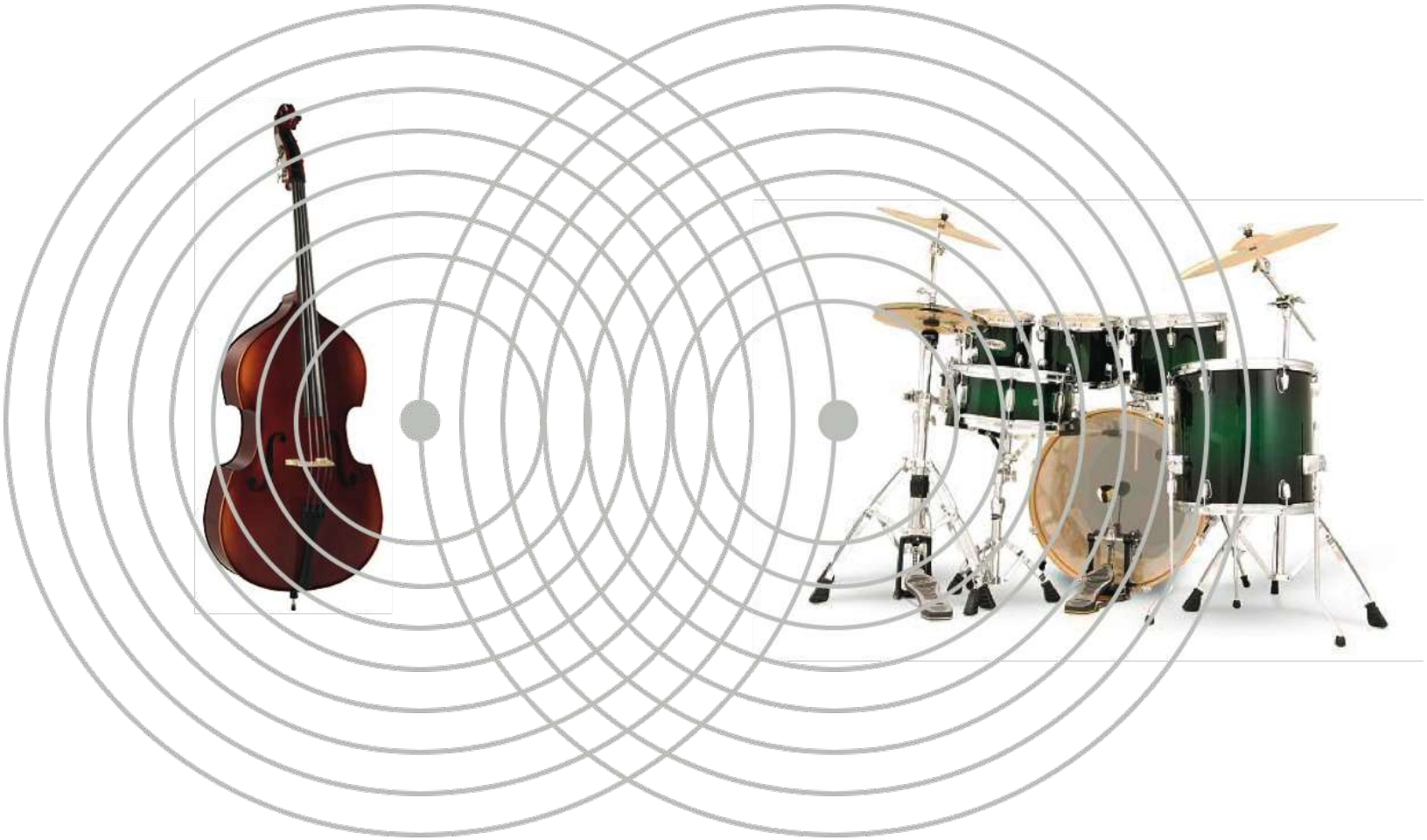
15 ms Delay

5 ms Delay

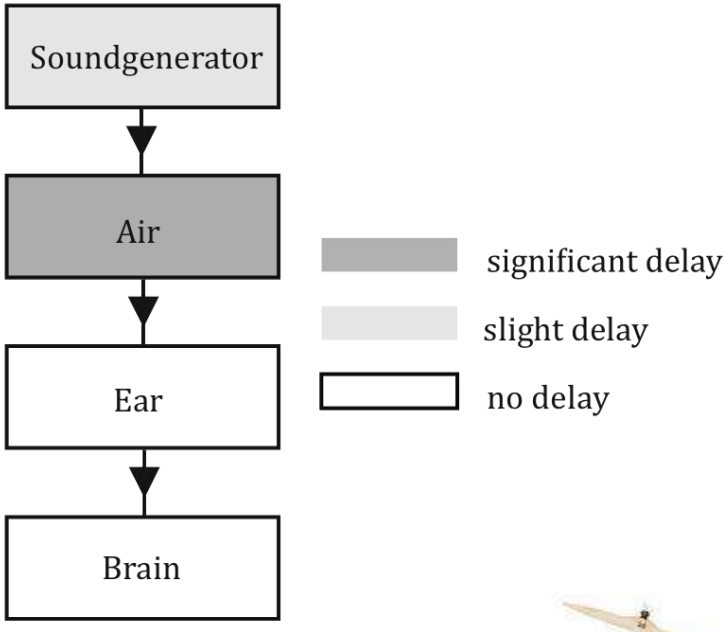




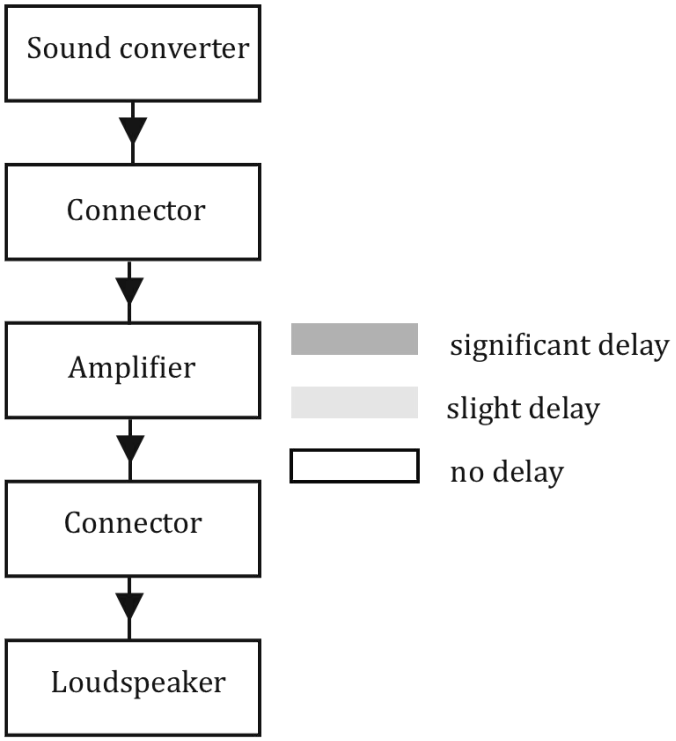
Realistic Interaction Approach (RIA)



Speed of sound : 343 m/s

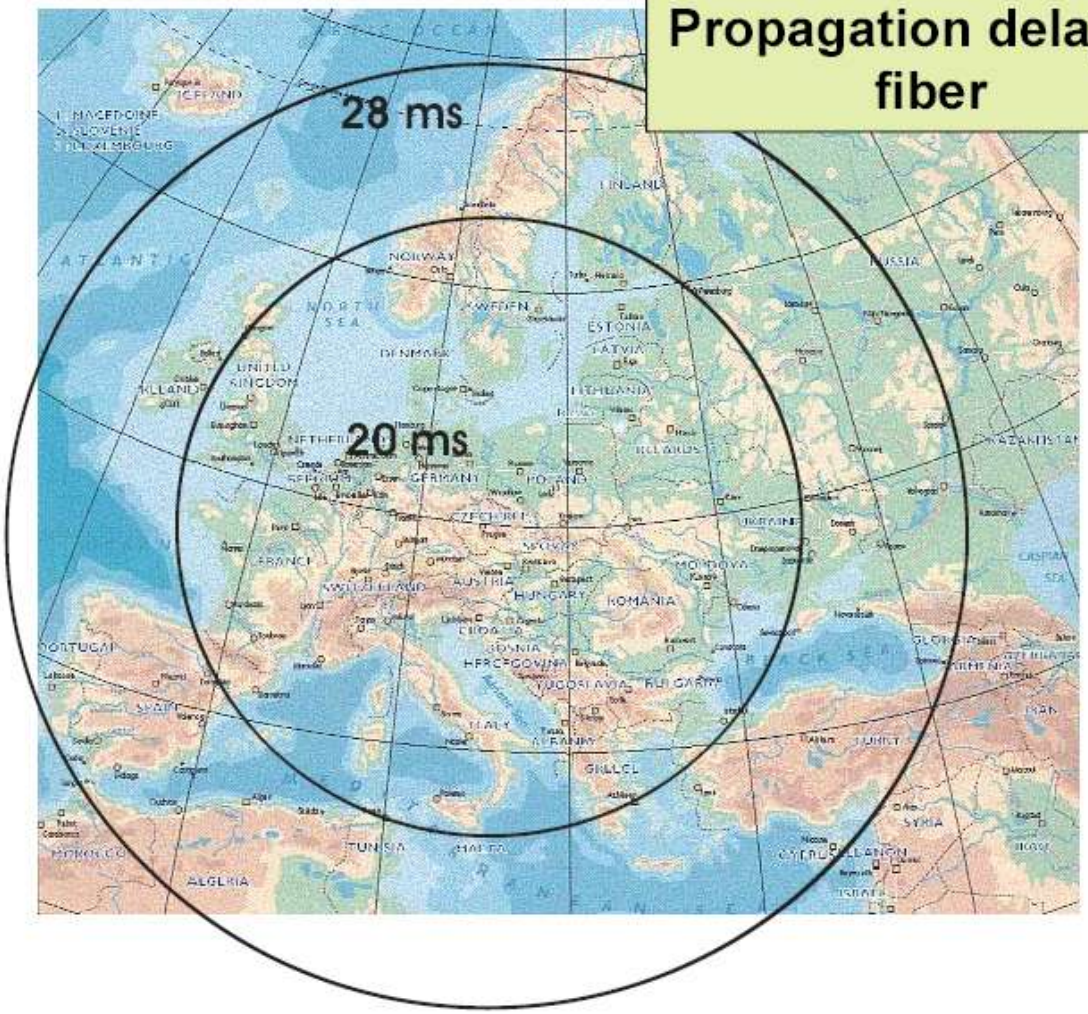

Soundgenerator
Air
Ear
Brain
significant delay
slight delay
no delay

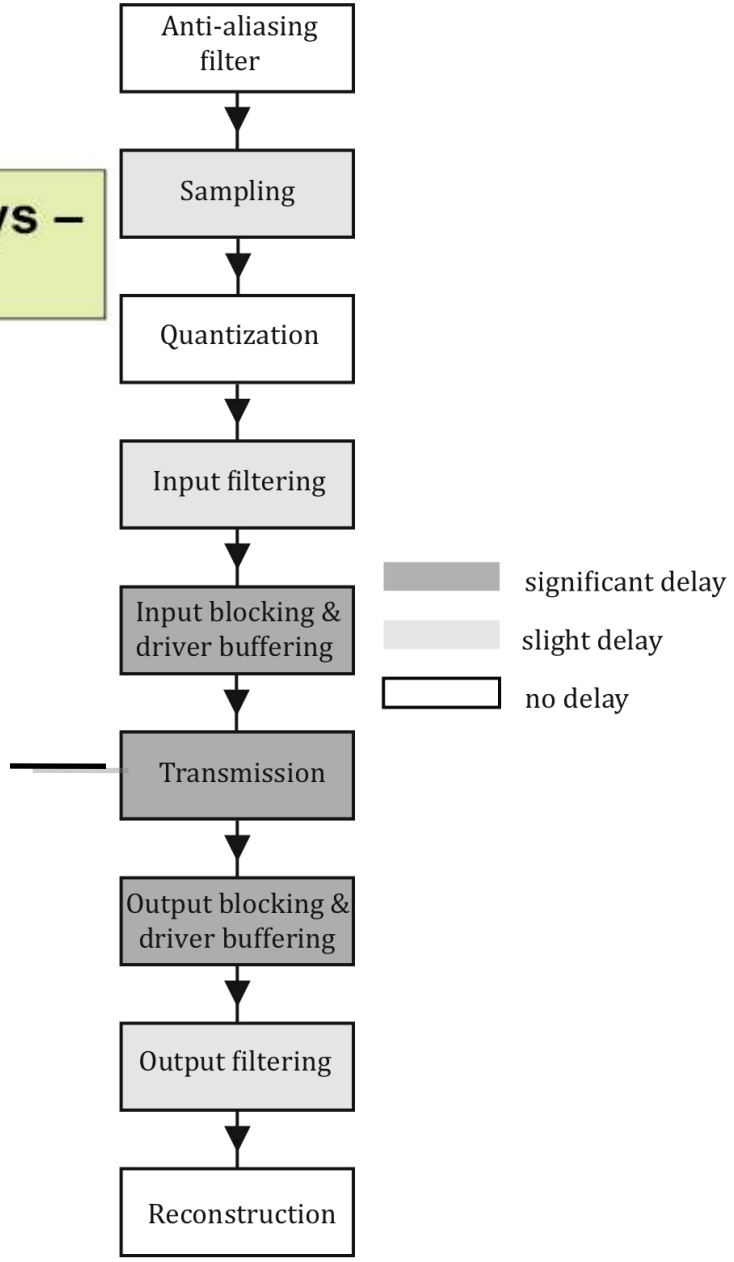
~ 8,5 m

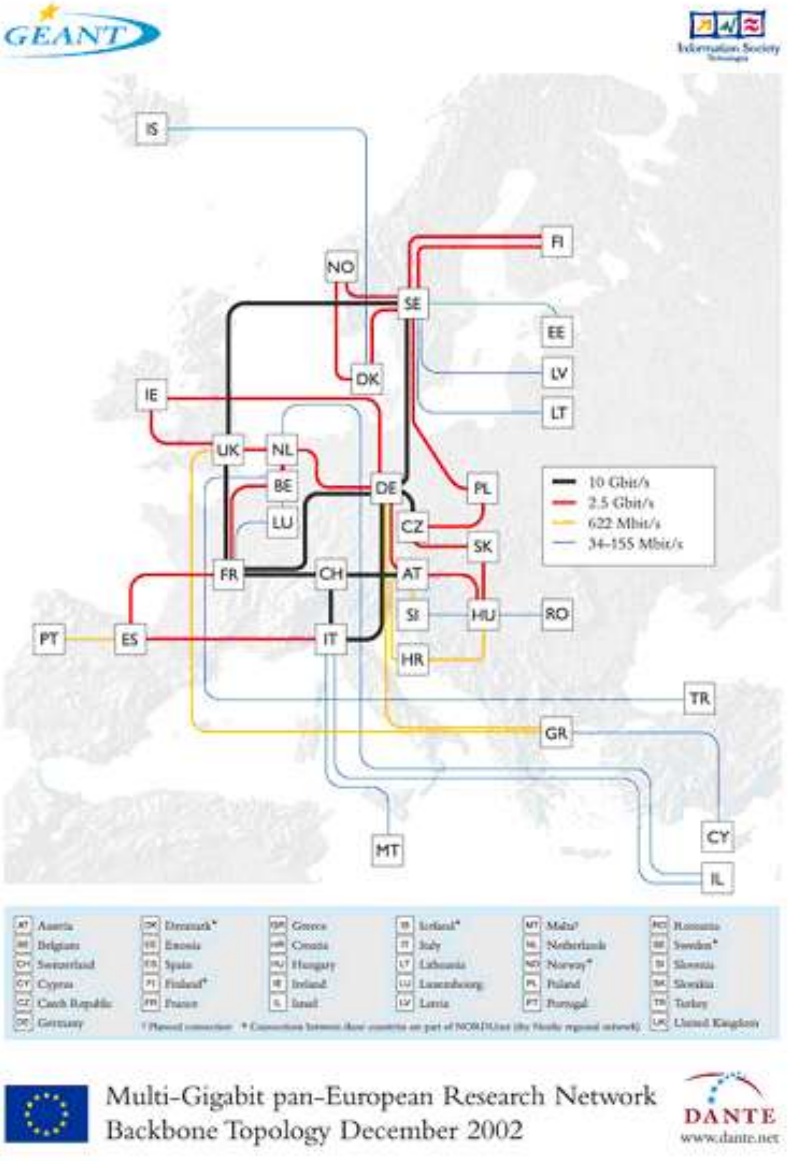


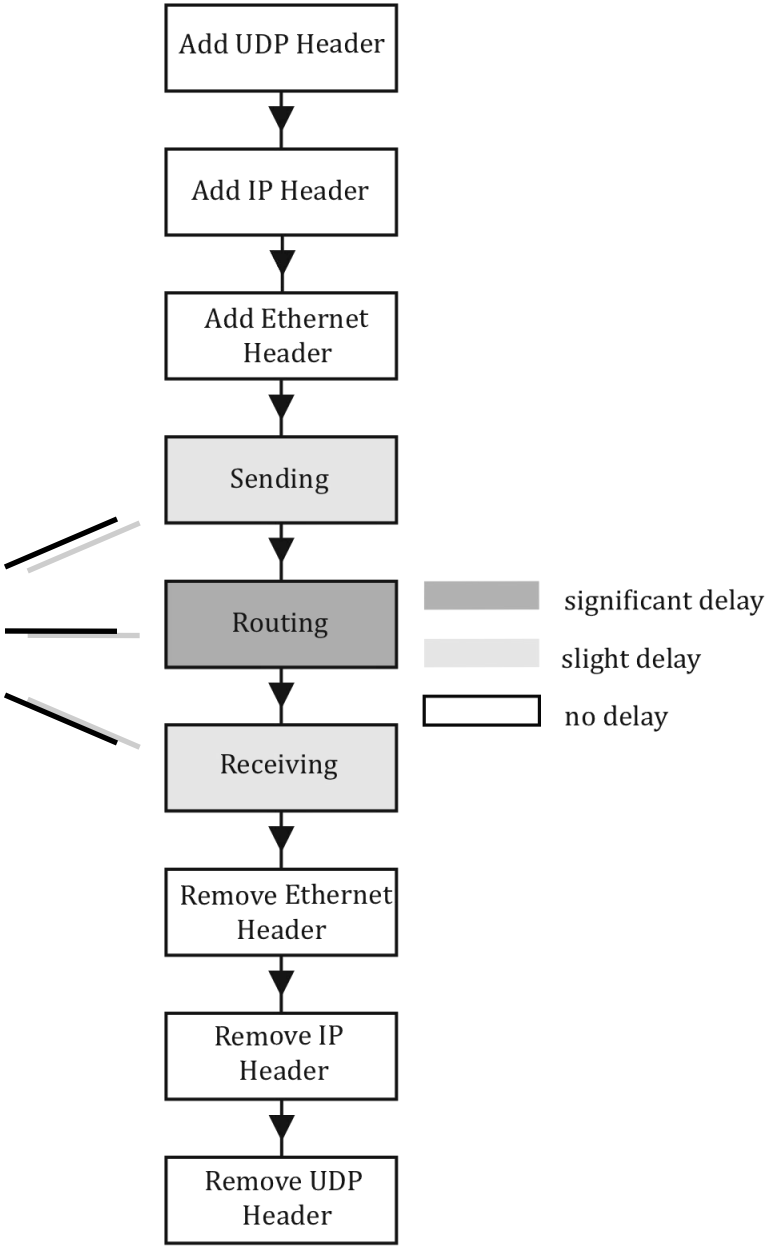
speed of light : 300.000 km/s (factor ~ 900.000 !)

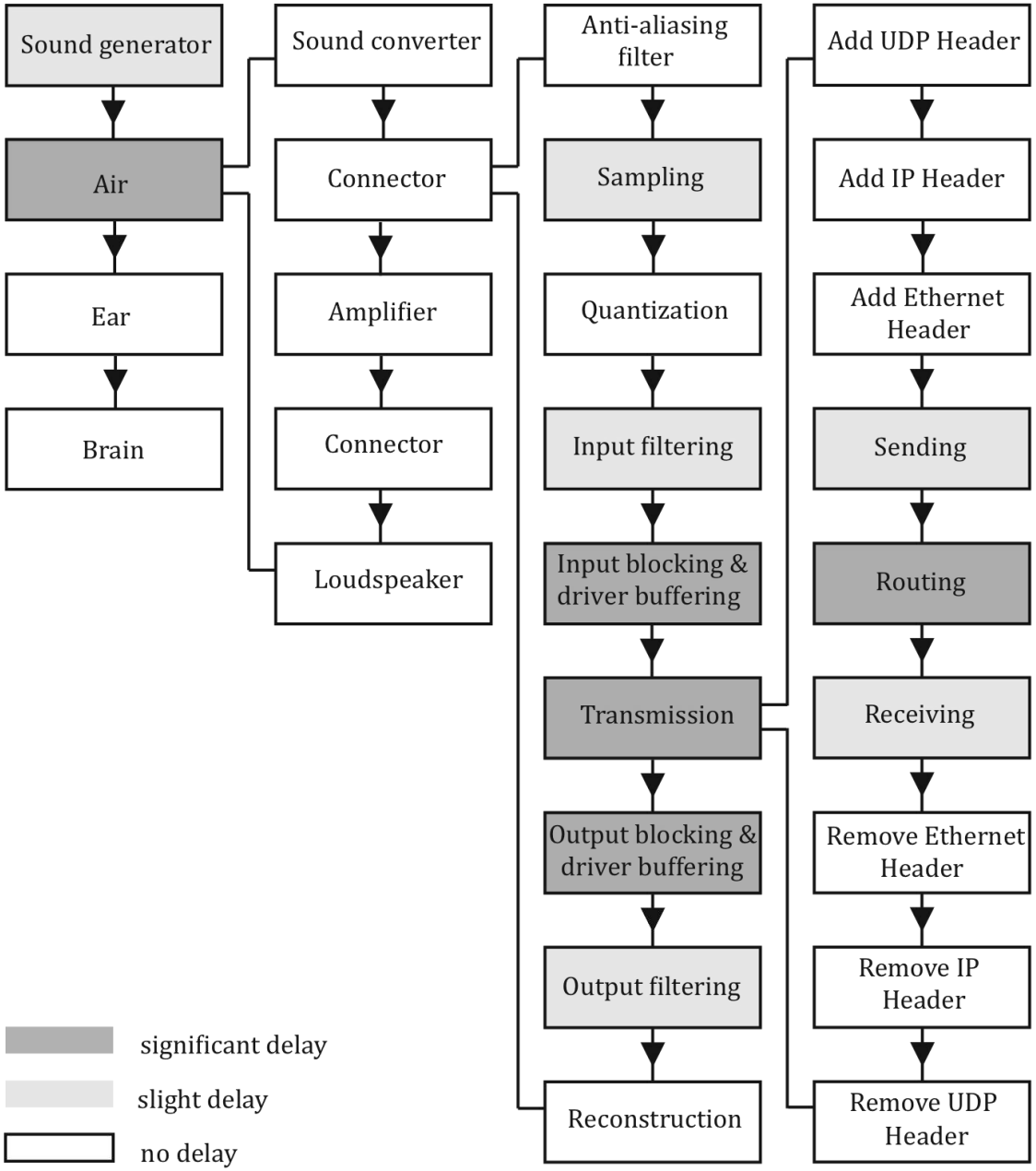
~7500 km


Propagation delays – fiber
28 ms
20 ms

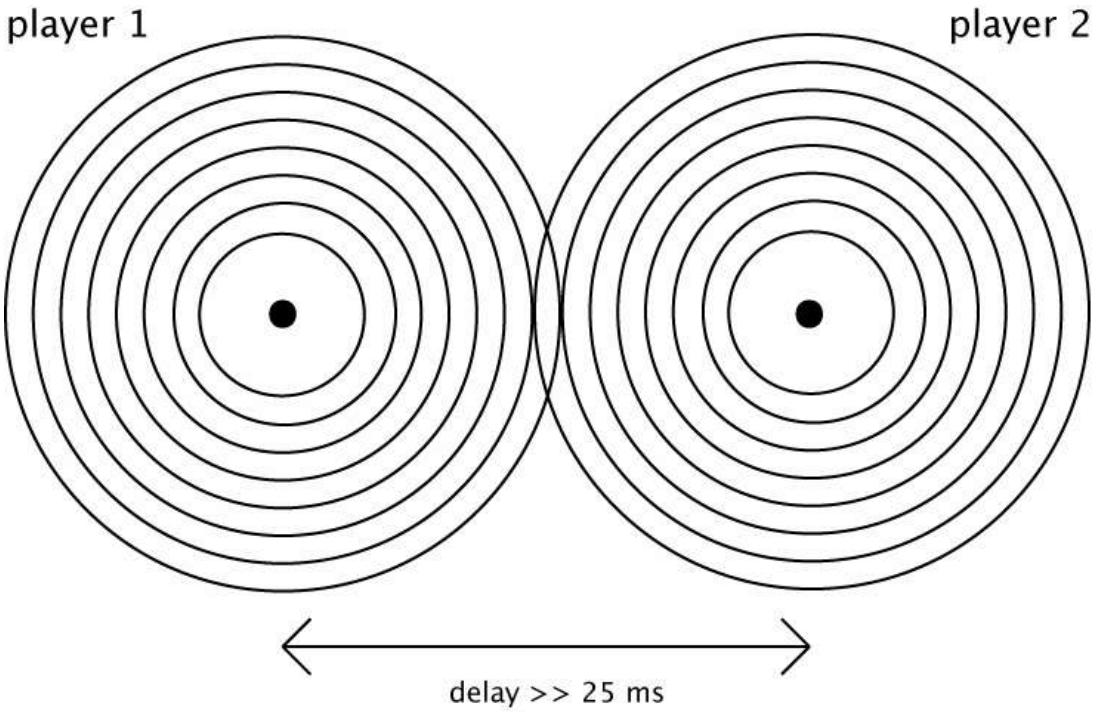

Anti-aliasing filter
Sampling
Quantization
Input filtering
Input blocking & driver buffering
Transmission
Output blocking & driver buffering
Output filtering
Reconstruction
significant delay
slight delay
no delay


GÉANT
Information Society
IS
NO
FI
SE
EE
DK
LV
LT
IE
UK
NL
BE
DE
PL
LU
CZ
SK
FR
CH
AT
SI
HU
RO
PT
ES
IT
HR
TR
GR
MT
CY
IL
10 Gbit/s
2.5 Gbit/s
622 Mbit/s
34–155 Mbit/s
Multi-Gigabit pan-European Research Network
Backbone Topology December 2002
DANTE
www.dante.net


Add UDP Header
Add IP Header
Add Ethernet Header
Sending
Routing
Receiving
Remove Ethernet Header
Remove IP Header
Remove UDP Header
significant delay
slight delay
no delay


Sound generator
Air
Ear
Brain
Sound converter
Connector
Amplifier
Connector
Loudspeaker
Anti-aliasing filter
Sampling
Quantization
Input filtering
Input blocking & driver buffering
Transmission
Output blocking & driver buffering
Output filtering
Reconstruction
Add UDP Header
Add IP Header
Add Ethernet Header
Sending
Routing
Receiving
Remove Ethernet Header
Remove IP Header
Remove UDP Header
significant delay
slight delay
no delay

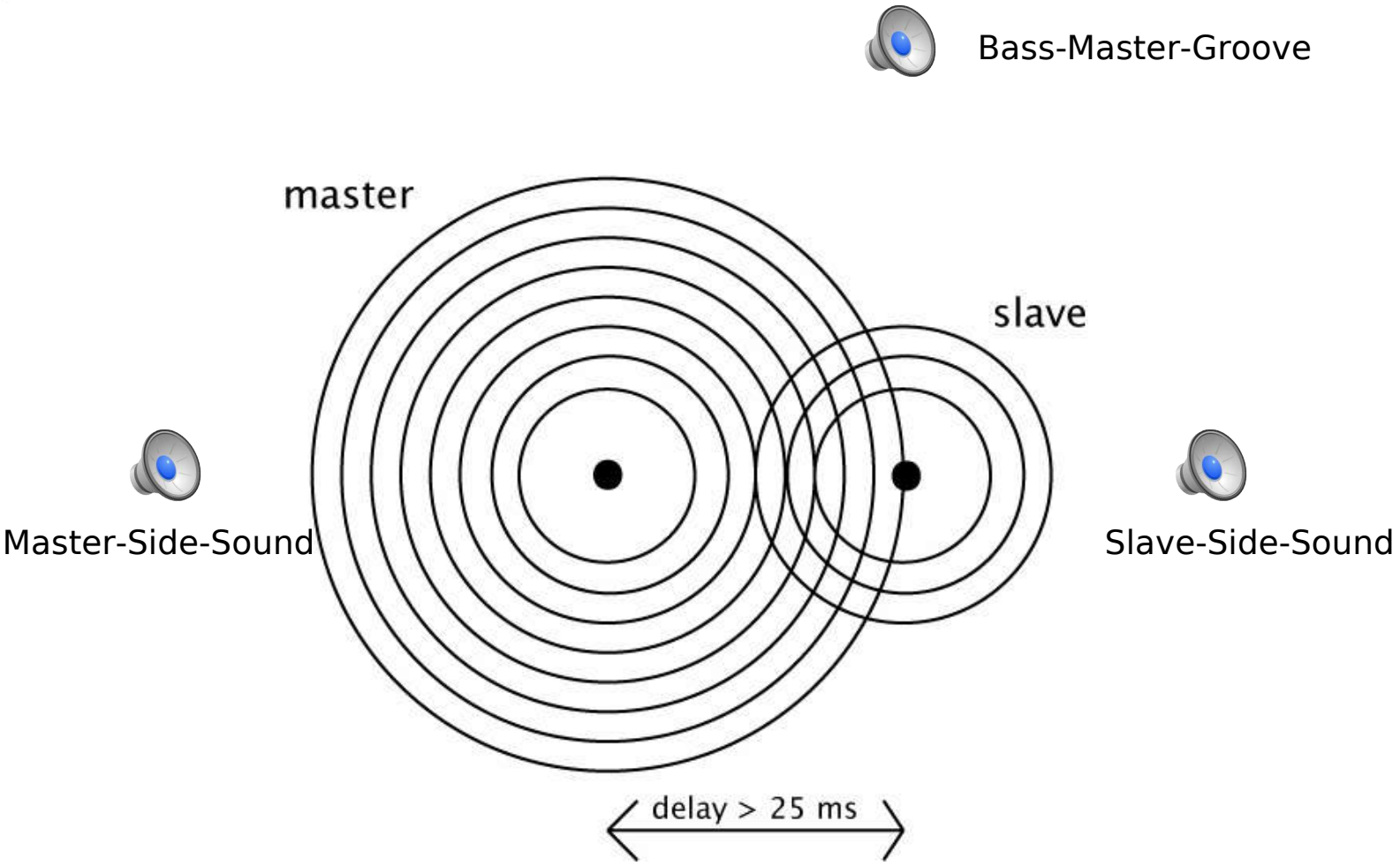
3.) Alternative Approaches



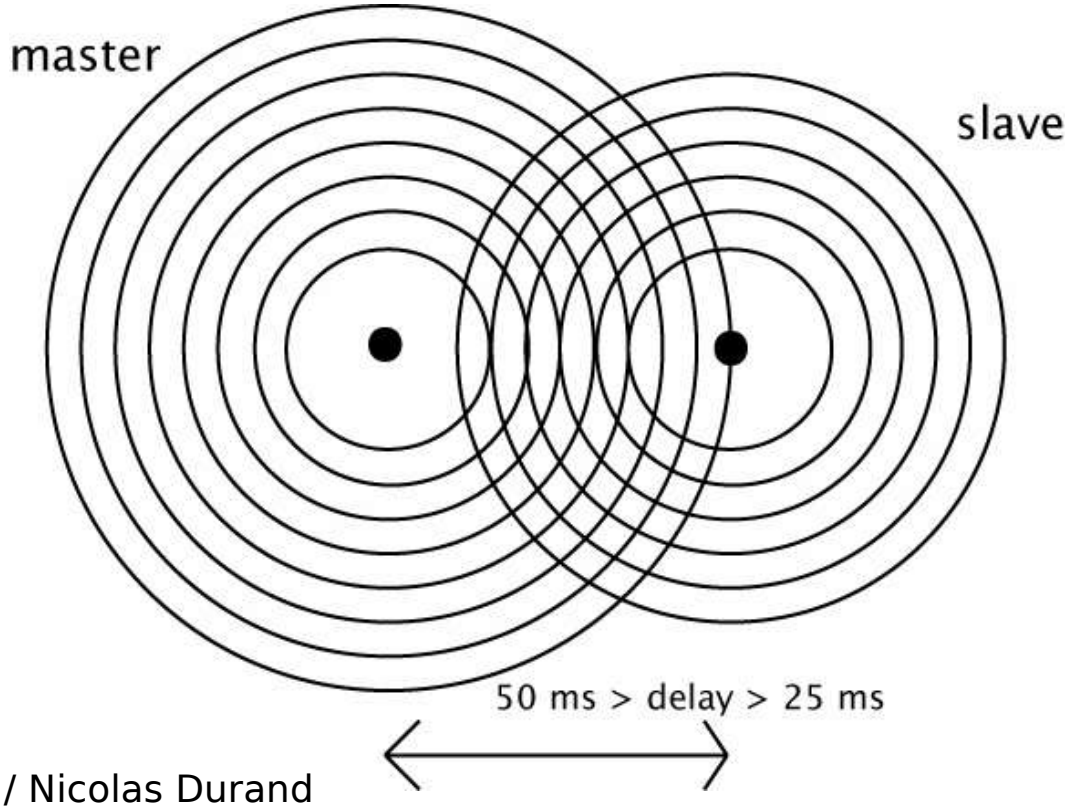
Strings Apart
Pedro Rebelo, Mark Applebaum
SARC / CCRMA (8141 km / ~ 100 ms)

Latency Accepting Approach (LAA)

3) Alternative Approaches



Master/Slave Approach (MSA)

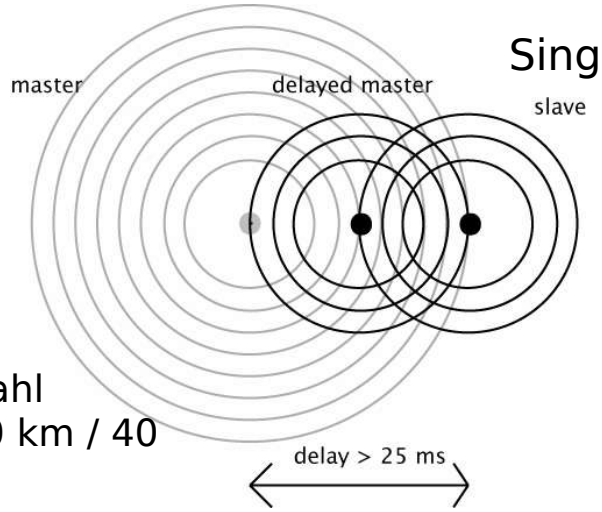


Alexander Carôt / Nicolas Durand
Lübeck / Paris (~ 751 km / 35 ms)

Laid-Back Approach (LBA)

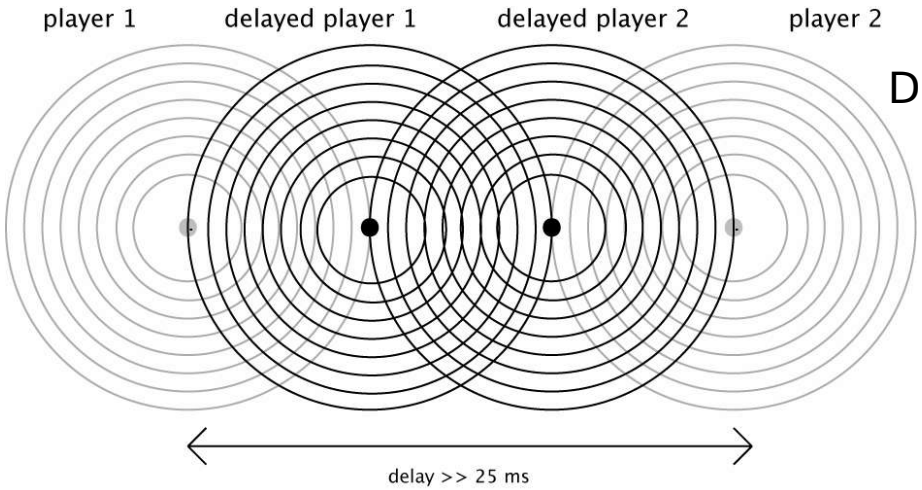
3) Alternative Approaches

Single delayed feedback (SDF)



Alexander Carôt / Michael Stahl
Lübeck-DSL / Erlangen (~520 km / 40 ms)

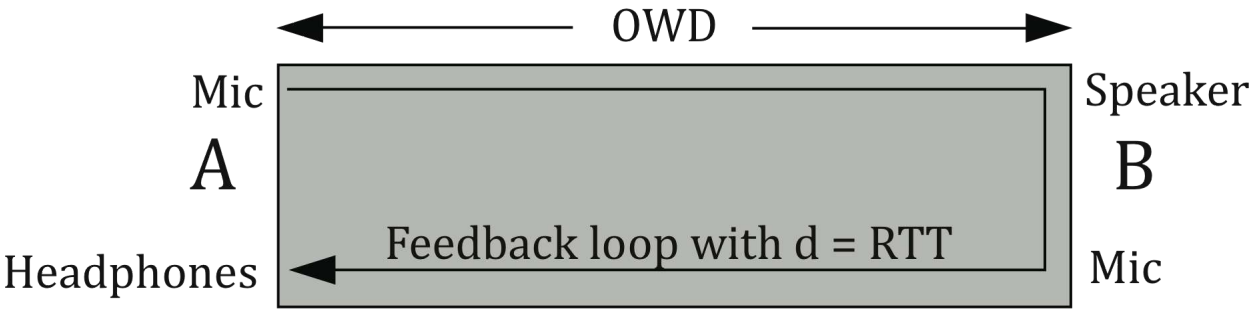
Dual delayed feedback (DD



Delayed Feedback Approach (DFA)

3) Alternative Approaches

- EDAL = 0 ms (!)
- Approach: Application of SDF (single delayed feedback)



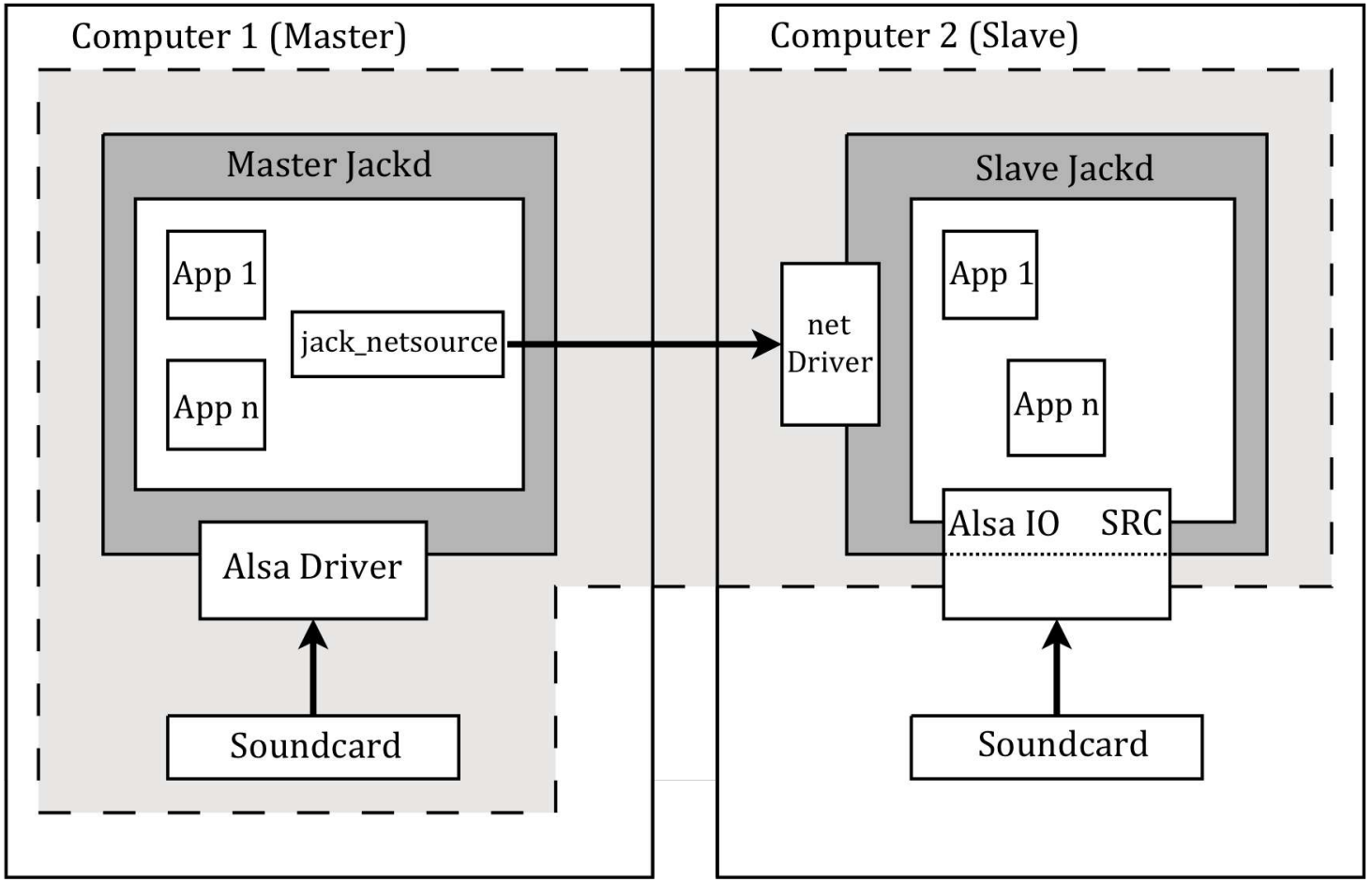
4.) Interconnection of remote electronic sequencers (Netjack)

History of Netjack1

- Implemented as a patch to jack in 2005.
- Committed to jack-svn 2008-03-06
- In November 2009 I got aware of CELT and added support for that.
- Then started making netjack more robust against packet loss.
- Reimplemented the algorithm used in alsa_io

Synchronise jack-transport

- No vari-speed in jack.
- Only possibility is synchronising sample-clock
- Thats the idea behind netjack.
- Jack-driver which syncs one instance of jackd to another one.


Computer 1 (Master)
Computer 2 (Slave)
Master Jackd
App 1
jack_netsource
App n
Alsa Driver
Soundcard
net
Driver
Slave Jackd
App 1
App n
Alsa IO
SRC
Soundcard

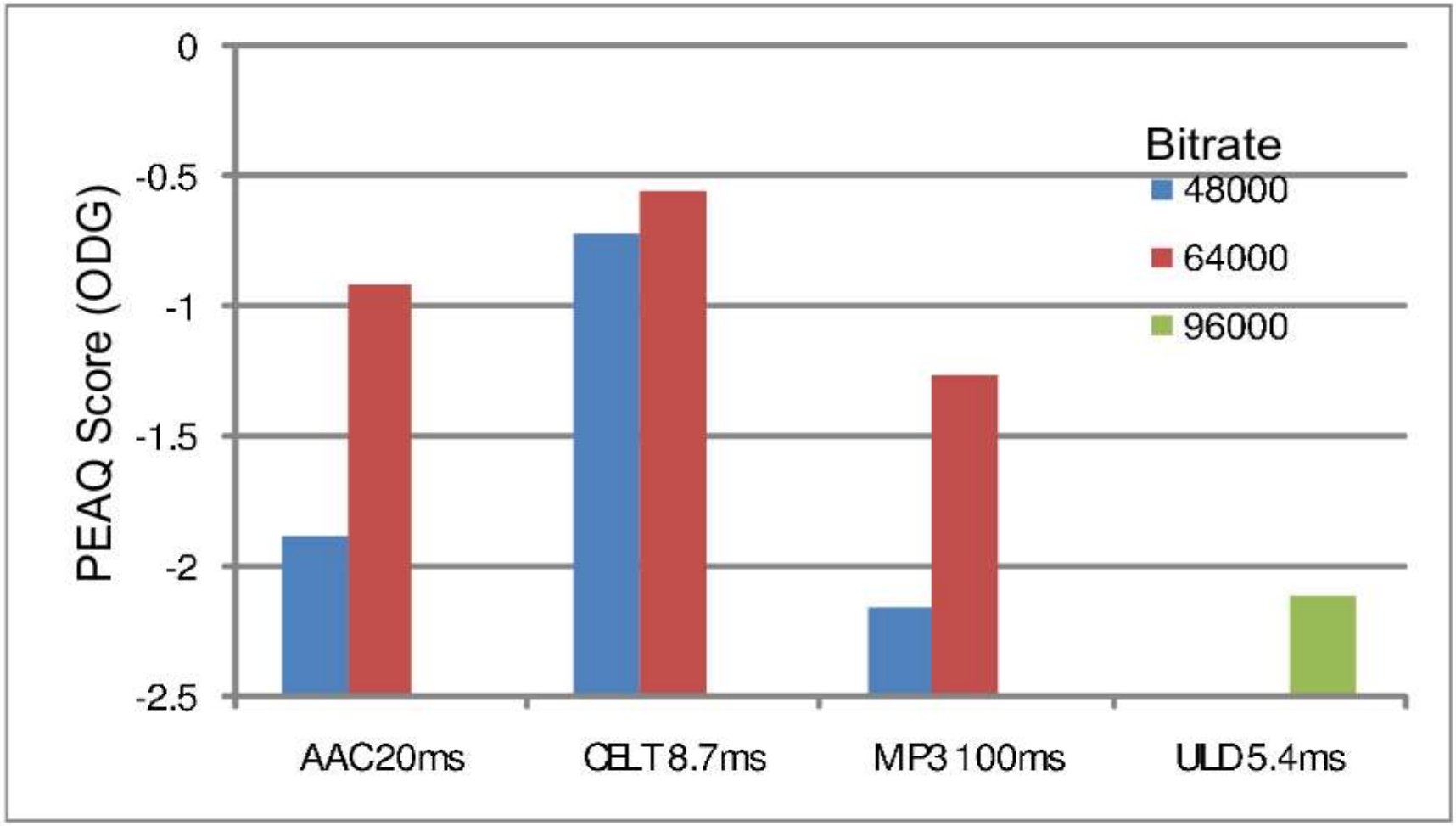
Codecs

- Mainly 2 types of codecs.
  - High delay (mp3, vorbis, aac)
    - Need >100ms of audio to emit a compressed byte.
    - Suitable for music.
  - Speech Codecs
    - Speex, gsm....
    - Low latency
    - Not suitable for music.
- Need low-latency music codec

CELT

- Closes gap between vorbis and speex.
- xiph.org (BSD style)
- Nice music quality.
- Support for Packet Loss Concealment
- Many different latencies, and bitrates supported.

Low-latency Codec comparison



Bit rate reduced, go internet ?

- With the reduced required bitrate it is theoretically possible, to create a netjack link over internet.
- OHNOES. where iz packet ?
- A packet may either be late or get lost on the internet.
- Netjack was ignoring this fact, because it doesnt happen on LAN.

How to decide if packet is lost ?

- Easy on the master. It expects a packet with a specific sequence number in process_callback().
- On the slave i am using a deadline, which is constantly calibrated. So that a „reply“ to lost packet is still reaching the master in time.

so... netjack1 scales now.

- Zero latency mode.
- 1-3 periods of Roundtrip on LAN
- Arbitrary latency for an internet link.

Why not Netjack2 ?

- „Jack1 is dead, stop hacking it.“ © sampo_v2
- Netjack2 was written while i was pretty inactive. No backport to jack1 was done.
- Its more comfortable, but purely targeted at LAN. (broadcast)
- Adding CELT support to netjack1 took 1 hour. It was my code.
- The packet assembly code needed only small mod, to become a jitter-buffer.

Both protocols waste bandwidth

- Netjack1 has a huge packet header
  - 48 bytes per packet. (most of it has redundant data)
- Netjack2 uses a second sync packet.
  - Also a lot of overhead when encapsulated.
- so... i think, we want netjack3.

Conclusion

- We can use netjack over Internet.
- Needs a nice frontend to setup connections.
- We have a big mess with 2 implementations of jack and 2 implementations of netjack.
- It looks like the mess will get bigger (netjack1 for jack2 is in the pipe)
- Hopefully netjack3 will not make it even worse.